REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*: 09-JUL-2003
2. REPORT TYPE: Conference Proceedings, (not refereed)
3. DATES COVERED *(From - To)*:

4. TITLE AND SUBTITLE: Environmentally Adaptive And Through-The-Sensor Efforts At NRL

5a. CONTRACT NUMBER:
5b. GRANT NUMBER:
5c. PROGRAM ELEMENT NUMBER: 0603704N
5d. PROJECT NUMBER:
5e. TASK NUMBER:
5f. WORK UNIT NUMBER: 74-7441-A3

6. AUTHOR(S)
MICHAEL M HARRIS WILLIAM E AVERÁ LEONARD D BIBEE DONALD J WALTER
BRIAN S BOURGEOIS DONALD L BRANDON N. P. CHOTIROS ( )

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Research Laboratory
Marine Geoscience Division
Stennis Space Center, MS 39529-5004

8. REPORTING ORGANIZATION REPORT NUMBER: NRL/PP/7440--03-1021

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
SPAWAR PMW 150
4301 Pacific Highway
San Diego, CA 92110

10. SPONSOR/MONITOR'S ACRONYM(S): SPAWAR

11. SPONSOR/MONITOR'S REPORT NUMBER(S):

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release,distribution is unlimited

13. SUPPLEMENTARY NOTES

20031015 021

14. ABSTRACT

The Naval Research Laboratory 's Marine Geosciences Division is conducting research in Through-The-Sensor and Environmentally Adaptive Sensor Techniques. NRL's AutoSurveyTM system is an environmentally adaptive technique developed to minimize survey time in an area while obtaining the desired seafloor coverage. The effective swath of a multibeam survey system depends on water depth, sound velocity conditions, seafloor properties, and sensor settings. AutoSurvey monitors these conditions and using intelligent navigation adjusts ship track accordingly to achieve a desired swath overlap. The real-time system processes the edge of good swath data at the end of each survey line and lays down the next survey line on the fly based on actual coverage. As a result excessive overlap in deep areas and data gaps in shoal areas are avoided. AutoSurvey timesavings are slope dependent. Results from actual surveys have demonstrated timesavings of 10% with as little as 1o of slope, and up to 60% for rugged terrain. AutoSurvey has been transitioned to the Naval Oceanographic Office (NAVOCEANO) for use on their T-AGS vessels. Additionally NRL has worked with ARL/UT in the development of a real-time situational awareness tool for the SQQ-32 mine hunting sonar. In this environmentally adaptive technique, real-time reverberation statistics from the SQQ-32 and target signal computations involving the sound speed profile are used to compute sonar detection performance. The Sonar Performance Monitoring System displays detection performance as a function of bearing and range in four colors, good to poor, responsive to changing environmental conditions and the sonar configuration.
Through-The-Sensor (TTS) concepts use fleet assets to collect tactical environmental data that can be used to refresh the environmental picture. NRL's Acoustic Seafloor Classification System (ASCS) uses inversion and signal processing techniques to determine acoustic impedance and seafloor properties.

15. SUBJECT TERMS
through-the-sensor, environmentally adaptive sensor

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified	Unlimited	11	Michael Harris / 228-688-4420

TTCP MAR/TP-13, Sydney, Australia, 8-13 September 2003

Environmentally Adaptive and Through-The-Sensor Efforts At NRL

Mike Harris, Will Avera, Dale Bibee, Don Walter, Brian Bourgeois, Donald Brandon
Naval Research Laboratory, Stennis Space Center, MS 39529-5004
E-Mail: mike.harris@nrlssc.navy.mil
And
Nicholas Chotiros
Office of Naval Research, 800 North Quincy St., Arlington, VA 22217-5660
E-Mail: CHOTIRN@ONR.NAVY.MIL

Abstract

The Naval Research Laboratory 's Marine Geosciences Division is conducting research in Through-The-Sensor and Environmentally Adaptive Sensor Techniques. NRL's AutoSurvey™ system is an environmentally adaptive technique developed to minimize survey time in an area while obtaining the desired seafloor coverage. The effective swath of a multibeam survey system depends on water depth, sound velocity conditions, seafloor properties, and sensor settings. AutoSurvey monitors these conditions and using intelligent navigation adjusts ship track accordingly to achieve a desired swath overlap. The real-time system processes the edge of good swath data at the end of each survey line and lays down the next survey line on the fly based on actual coverage. As a result excessive overlap in deep areas and data gaps in shoal areas are avoided. AutoSurvey timesavings are slope dependent. Results from actual surveys have demonstrated timesavings of 10% with as little as 1° of slope, and up to 60% for rugged terrain. AutoSurvey has been transitioned to the Naval Oceanographic Office (NAVOCEANO) for use on their T-AGS vessels. Additionally NRL has worked with ARL/UT in the development of a real-time situational awareness tool for the SQQ-32 mine hunting sonar. In this environmentally adaptive technique, real-time reverberation statistics from the SQQ-32 and target signal computations involving the sound speed profile are used to compute sonar detection performance. The Sonar Performance Monitoring System displays detection performance as a function of bearing and range in four colors, good to poor, responsive to changing environmental conditions and the sonar configuration.

Through-The-Sensor (TTS) concepts use fleet assets to collect tactical environmental data that can be used to refresh the environmental picture. NRL's Acoustic Seafloor Classification System (ASCS) uses inversion and signal processing techniques to determine acoustic impedance and seafloor properties. Classification of surficial seafloor sediments has been demonstrated using normal incidence beams from the Navy standard UQN-4 Fathometer, and AQS-20 mine-hunting sensor. Similar information has been extracted from EM-121 multibeam systems using backscatter data. Signal and image processing algorithms were also developed to produce multibeam bathymetry from the AQS-20 mine-hunting sonar. TTS work includes transitioning these capabilities for use with tactical decision aids, environmental assessments, and integration into historical databases at NAVOCEANO.

1. Introduction

With the present state of world political volatility, the quick response of U.S. naval forces under the Sea Strike concept, and decreased access to exclusive economic zones worldwide, it is becoming increasingly apparent that environmental data relevant to tactical operations cannot be obtained through routine surveys but instead must be acquired from combatant sensor systems and used in near real-time. Combatant systems will be the first and perhaps the only systems to enter an area of operation before conflict begins. This issue was clearly highlighted in Operation Iraqi Freedom.

A recent article from "Inside the Navy"[1] concerning a speech by Jim Thompson, deputy to PEO-LMW, said "Recent military operations have proved the Navy's arsenal remains more weapons-rich than sensor-rich," he said suggesting the service must distribute more sensors to the field, and fast." Mission effectiveness can be severely degraded by less than optimum environmental conditions. Environmentally adaptive and 'Through the Sensors' (TTS) initiatives from NRL, the Oceanographer of the Navy, and ONR have been addressing this issue specifically with individual sensor systems (AQS-20, AN/UQN-4A, BQN-17, SQQ-32) to provide the environmental data needed for the optimal operation of combatant systems.

The next section of this paper discuss two environmentally adaptive efforts: AutoSurvey and Sonar Performance Monitoring System. Highlights from five Through The Sensor research projects are presented in section 3. The final section discusses a data handling program, TEDServices, that moves information to the warrior.

2 Environmentally Adaptive Efforts

Littoral environments are difficult to characterize due to spatial and temporal variability. Naval operations require a realistic view of the battle space environment measured as efficiently as possible. Efficiency in terms of less time to collect measurements is important. Correctly estimating the environment is also vital to system performance, for instance in terms of accurate detection ranges.

2.1 Autonomous Survey Techniques

NRL has developed an autonomous survey system, AutoSurvey, for swath surveys that can drastically reduce total survey time required for a given area. AutoSurvey adapts ship track based on changing swath width coverage that varies due to changing environmental factors.

AutoSurvey is an autonomous, environmentally adaptive approach to bathymetric surveying[2]. The technique was developed to improve the efficiency of multibeam bathymetric surveys providing swath coverage of the seafloor. During a survey, AutoSurvey takes over the vessel's autopilot, lays down waypoints on the fly, and provides the desired data coverage of the sea floor based on real-time quality constrained data versus predicted sensor coverage.

Modern multibeam bathymetric sonars generate swaths that have a fixed angle of coverage. Consequently, the actual horizontal width of the swath, or sensor coverage, varies with ocean depth, sensor performance and environmental conditions. The traditional approach of running a series of survey lines whose spacing is based upon the shallowest depth in a survey area and the nominal specification of sensor swath angle typically results in both data gaps and areas of excessive coverage (which is wasted time). The AutoSurvey system analyzes the collected bathymetry data in real-time, and during the end-of-line vessel turn it computes the waypoints for the next survey line. The waypoints generated by AutoSurvey ensure no gaps in the data and minimize excess coverage using a variety of adaptive line methods.

The AutoSurvey software was tested during 6 sea trials and successfully validated on the USNS MARY SEARS near Key West, Florida in August 2002. The AutoSurvey system will become a permanent part of NAVOCEANO's Integrated Software System (ISS-60) with the release of ISS-60 version 3.2. With this release, AutoSurvey will be available on all T-AGS class survey ships and HSLs (Hydrographic Survey Launches).

AutoSurvey reduces the operator load for routine hydrographic surveys and, more importantly, it can reduce survey time by as much as 60% in areas with rough bottom terrain as compared to traditional methods of surveying (see figure 1).

	% Coverage	Line Length (m)	Line Length Savings
Ladder	98+	72556	Baseline
Adaptive Parallel	98.53	59634	18%
Linear Regression	97.35	46434	36%
Piecewise Linear	98+	50050	31%

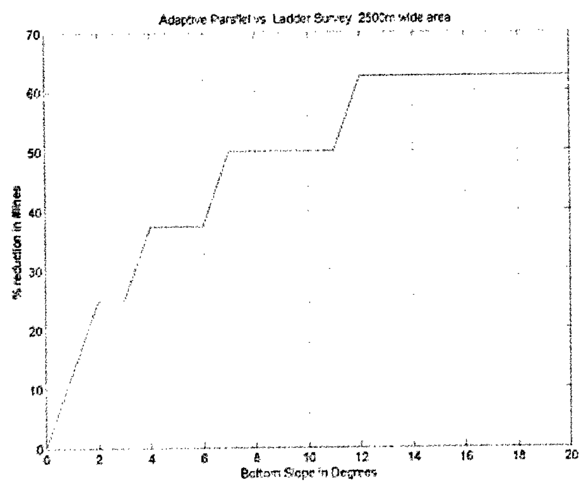

Figure 1
Right: Relative Line Length Savings from survey near Dry Tortugas, FL; Left: Slope affect on survey time

NRL is currently working on the development of a survey planner.[3] The AutoSurvey Planner (ASP) will provide realistic survey simulation capabilities to the survey operations team. ASP will allow hydrographers to determine the most efficient approach for surveying an area prior to moving into the area. Inputs include the vessel sensor specifications, the survey area and the first line to run, a digital terrain map of the area and vessel speed. The output from a run includes waypoints generated, vessel track, sensor data coverage, and survey statistics. Survey statistics include the amount of time the vessel was inside the survey bounds, the amount of time the vessel was outside the bounds during alignment and turns, the total time of the survey, the area inside the survey bounds and detailed coverage information. The system will undergo final acceptance tests and transition in 2004.

2.2 Sonar Performance Monitoring System

ARL/UT has developed a Sonar Performance Monitoring System (SPMS) for the SQQ-32 mine hunting sonar that displays sonar detection performance based on real-time reverberation statistics from the SQQ-32 and target signal computations involving the sound speed profile. SPMS displays sonar performance as a function of bearing and range providing the operator instant feedback from changing sonar settings and environment.

The SQQ-32 is a variable depth mine hunting sonar with 28 beam pairs covering an approximate 70-degree steer able sector. The Applied Research Laboratory of the University of Texas (ARL/UT), developed a sonar performance monitoring system (SPMS)[4], that quantifies the sonars performance as a function of range and bearing within a given sonar sector. The system was demonstrated at a MIREM9 exercise aboard the USS Pioneer (MCM-9) in 1999, and aboard the USS Champion (MCM-4) in 2000. SPMS uses background noise and reverberation statistics measured directly through the sonar, and a computed target signal level, to produce a signal to noise ratio as a function of position within the sonar field of view. Instead of attempting to quantify the components of the noise separately, background noise and reverberation levels are measured directly and in real-time.

An SQQ-32 operator is looking for targets (mines with given target strengths) in an environment that has changing noise levels, while using a fixed acoustic source level. Detection performance (signal to noise ratio) is calculated from the sonar equation by subtracting the total noise level from the signal. The signal is the source level plus the target strength minus the two-way propagation loss (a function of sound speed and the sound speed profile). The total noise level includes ambient noise (sea state dependent), system self noise, and reverberation noise from the surface, bottom and volume. Because the environment varies, the noise level is constantly changing and thus detection performance changes too.

SPMS provides the operator information on changes in detection performance. To adapt to the changing environment the sonar operator can vary pulse length, sonar depression angle, and sonar depth. The operator also inputs a measured sound speed profile that is used to make ray-bending calculations and determine propagation losses. Total noise is measured directly. SPMS displays detection performance as a function of bearing and range in four colors, good to poor, responsive to changing environmental conditions and the sonar configuration, Figure 2. Using the SPMS as a guide, the operator can optimize detection performance.

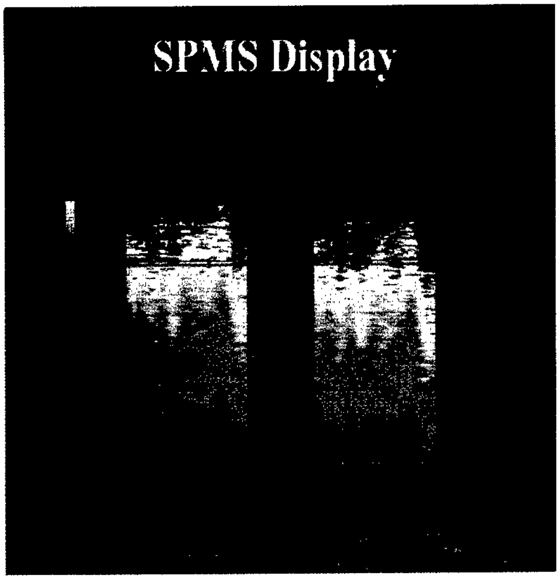

Figure 2
Sonar Performance Monitoring System Display showing signal performance versus bearing & range for the upper and lower sets of beams

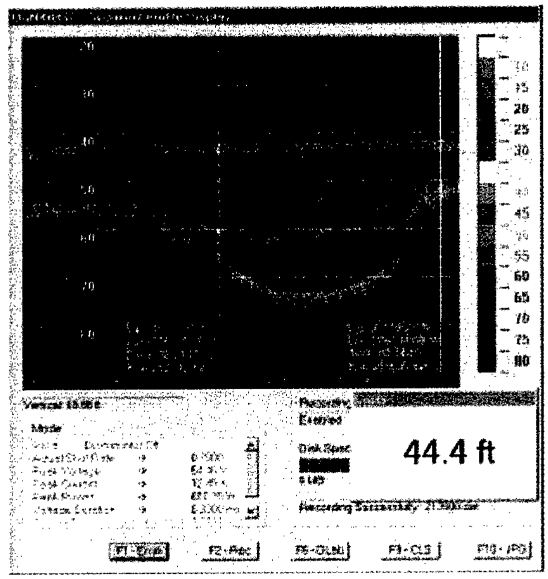

Figure 3
UQN-4 Bottom Sediment Profile Display showing acoustic impedance versus depth along the ship track

3 Through the Sensor Efforts

The TTS concept allows environmental data to be collected by tactical MCM sensors for use in tactical decision aids. The notion is to improve situational awareness by exploiting the environment for tactical advantage. TTS concept is minimally intrusive to the tactical sensor system, typically through software modifications. Additionally TTS does not interfere with the primary mission, safety or affect vulnerability.

TTS data is needed to assemble the environmental picture. Environmental support for mine warfare operations includes supplementing historical data sets with measurements in theatre. These real-time measurements are used to verify historical information, fill in gaps, replace perishable data, and provide new information.

Many types of environmental data are needed in the littoral including bathymetry, imagery, sediment type, water properties, etc. Bathymetry is required not only in mine warfare tactical decision aids but also for safety of navigation, acoustic propagation models, wave and surf forecast models, and tidal models. Imagery is used in mine warfare to determine seafloor roughness and clutter density. Sediment data is needed for mine burial models, as an input to establish lane spacing for mine hunting, and for acoustic models.

3.1 UQN-4 Bottom Sediment Classifier

The fathometer feed from the UQN-4 transducers on MCM ships is being adapted to do acoustic sediment classification. Sediment classification using the UQN-4 fathometer on MCM ships was demonstrated aboard USS CHAMPION in CY2001 in the

Gulf of Mexico and on the USS DEXTROUS operating out of Bahrain. This data provides situational awareness about bottom type to MCM operators and provides insight on mine burial potential in the operational area. The data is also available to the Naval Oceanographic Office for incorporation into historical databases and environmental data uploads to MEDAL. Permanent installation options are being assessed for the upcoming budget cycle including integration with the Battlespace Profiler.

Theoretically, acoustic sediment classification software[5], developed at NRL, converts broadband acoustic time series information into sediment acoustic impedance. Using empirical data, impedance values are then related to a bottom type (mud, sand, rock) and mine burial potential. The Bottom Sediment Classifier (BSC) software runs in the MCM ships combat information center (CIC) on the same computer running the SQQ-32 SPMS described above. BSC taps into the UQN-4 transducer data feed at the bridge fathometer display. The operator display in CIC shows the sediment profile in real-time, Figure 3, and the ship track, which is color-coded to indicate acoustic impedance or sediment type. Inferred sediment parameters are used for situational awareness. In the future, sediment parameters will be fed to MCM tactical decision aids.

3.2 BQN-17 Sediment Classification

NRL used the BQN-17 fathometer on two SSN's to map sediment properties. These demonstrations tapped off the BQN-17's data stream and processed the raw information with NRL's acoustic sediment classification system operating on a laptop computer. The system evaluated acoustic returns from the BQN-17 sonar and estimated sediment properties that can be used for tactical acoustic performance predictions.

System performance exceeded expectations. Subbottom sediment layers were mapped to depths of 20m below the seafloor, and good data were collected in water depths exceeding 2000 meters. In a post deployment oceanographic cruise, following the USS KEY WEST's data collection effort, sediment cores were taken along the submarine track. Agreement between the BQN-17 acoustic sediment data and the core data was excellent.

The hardware was installed on the USS KEY WEST during April 2001 in Pearl Harbor. The system was activated and demonstrated at sea during the following summer. The USS PORTSMOUTH installation occurred in August 2003. Training in the operation of the system for ship's sonar personnel was provided, and the system was operated during their respective deployments. Options are being reviewed for permanently installing the system as part of the BQN-17A upgrade on 688 Class SSN's in FY03.

This added capability will allow collection of environmental data in denied areas. These data are potentially useful for onboard acoustic tactical decision aids as well as for additions to the Navy database in waters only accessible by submarines.

3.3 EM-121 Multibeam Sediment Characterization

NRL has developed software that converts backscatter information collected by multibeam bathymetric systems into surficial sediment types. NRL is working with the Naval Oceanographic Office to validate the software, SediMap™ . Beta versions 1.0 and 2.0, have been provided for use with backscatter from EM 121 and EM1002 multibeam bathymetry systems. The initial code met validation criteria using multibeam and ground truth data in the Onslow Bay area. NRL is currently testing the code in other areas with different bottom types and using different multibeam systems. Once operational this advanced software package will permit the Oceanographic Office to get additional information (bottom type) from multibeam bathymetry systems by processing the raw backscatter data.

In the SediMap system[6], the sonar hydrophone data is beamformed, calibrated and transformed into backscattering strength vs. grazing angle. The Mourad-Jackson backscatter model is used to invert the data via a simulated annealing technique to obtain mean sediment grain size. Tests on the inversion results agree very well with the ground truth sediment types in Onslow Bay, Key West, Arafura Sea, and Quinault (off the coast of Washington state).

Seafloor bottom type databases are currently produced by combining geologic samples, information available from literature, and other sources. With the SediMap software system, the Naval Oceanographic Office will be able to process existing and future raw backscatter data from their multibeam bathymetry systems to update these databases.

3.4 AQS-20 Environmental Data collection

The technical feasibility of extracting critical Mine Counter Measures environmental parameters from the new AQS-20 Mine Hunting Sonar was demonstrated using a Through the Sensors concept[7]. Single beam bathymetry, multi-beam bathymetry, and sediment properties were derived from the AQS-20 data stream that meet Mine Warfare Requirements. The documented results were based on AQS-20 flights conducted in June 1998, July 1999 and June 2001. The environmental data is to be used near real-time in tactical decision aids like the Mine Warfare Environmental Decision Aids Library (MEDAL) and post time to enhance historical databases.

The AN/AQS-20 is a variable depth, mine hunting sonar system designed to detect, classify and identify moored and bottom mines using side-scan, forward-looking, and Volume Search Sonar (VSS) systems from deep to very shallow water.[8] The system is designed to be towed from either the MH-60 helicopter or the AN/WLD-1(V) remote minehunting system. Environmental data can be extracted from the AQS-20 data through additional processing. The AQS-20 provides both a low-resolution mission data stream and a high-resolution data stream. Mission data tested was 2-bit intensity information with 1.4-yard range resolution. High-resolution data contained 16-bit beam intensity information at .1-yard range resolution. High-resolution data is required to extract multibeam bathymetry and sediment type.

The AQS-20 has several modes of operation each using different sensor combinations. In the *Single Pass Shallow* (SPS) Mode the Side Look Sonar (SLS) Data provides side-scan information to image the seafloor along a varying path that is a constant altitude above the seafloor. Single beam bathymetry can be extracted in this mode using altitude information from the Acoustic Doppler sonar. In the *Volume Mode* of operation the VSS sweeps a fan shaped area searching for moored mine shapes in the water volume while flying at a constant depth below the sea surface. VSS beam information can be processed to pick out bottom detections that equate to multibeam bathymetry, and the nadir beam can be processed for determination of sediment type.

NRL demonstrated[9] the ability to classify surficial seafloor sediments using several fleet sonars that acoustically illuminate the seafloor at near-normal-incidence. In March-June 2001, a comparative study was conducted near Panama City, FL. A UQN-4 surface-ship fathometer, a BQN-17 submarine fathometer, and a research transducer were installed on a research vessel and collected data over the same ship track. Ground truth data was collected in the form of sediment grab samples and analyzed for sediment type and grain size. Data was also collected using a helicopter-towed MCM sonar (the AQS-20/VSS) along the same tracks. In each case the data was processed through NRL's Acoustic Sediment Classification System (ASCS) in either a real-time or post-processed mode. All systems successfully delineated a transition in sediment type from sand to sandy-mud that was validated by the sediment samples.

Multibeam data collected by the AQS-20 VSS sonar in the June 2001 flight was compared with multibeam data collected in November 2001by the USNS LITTLEHALES equipped with an EM-1002 multibeam. VSS depth comparisons were within 1% of EM-1002 data.

In Dedicated MCM operations AQS-20 environmental information will be collected from the AN/WLD-1(V) Remote Mine Hunting System and/or MH-60 Helicopter and processed by a Mobile Environmental Team. Processed sediment and bathymetry data will be inserted into the Mine Warfare Environmental Decisions Aid Library (MEDAL) also known as the Mine Countermeasures Segment (MCMSEG) of the Global Command and Control System (GCCS). Once in MEDAL the environmental data will be used to help determine line spacing for mine hunting operations.

3.5 Clutter Density

Acoustic imagery from sidescan sonars is used to detect mine-like objects on the seafloor and to determine seafloor characteristics that impact mine-hunting operations. This information is used by MCM commanders to determine resource allocation, the time required to clear an area of mines, and the level of risk remaining after mine clearance operations are completed. The Naval Oceanographic Office uses interactive graphical methods to determine one of these characteristics, clutter density on the seafloor.

These methods are time-consuming and may produce different results from analyst to analyst. In order to reduce the time required to determine clutter density and to produce more consistent and repeatable results, the Naval Research Laboratory (NRL) developed and transitioned a real-time clutter detection algorithm that marks and clusters mine-like contacts according to mine warfare doctrine.

The software was tested on the "Common Data Set" provide by the *2nd International Conference on High-Resolution Surveys in Shallow Water.* The algorithm performed well correctly identifying clutter polygons. The algorithm failed in areas where the sonar made abrupt changes in altitude and direction. This occurred when the sonar was being turned or positioned to begin its next track. NRL's automated Clutter Detection and Clustering software has demonstrated greater than a 25X improvement in processing time for analyzing sidescan sonar data for clutter.

4 Data Handling

NRL has developed architecture, TEDServices[10], to provide the means to disseminate tactical environmental data and Through The Sensor information to sailors, weapon systems and MetOc data users. TEDServices provides the middleware infrastructure to transport and transform environmental data.

The Oceanographer of the Navy established a concept of operations to ensure the best data gets to the user. In that concept Production Centers (ex: the Naval Oceanographic Office, and the Fleet Numerical Meteorological and Oceanographic Center) generate atmospheric and ocean model predictions based on in-situ data. Domain Authorities (environmental data experts) examine data from multiple sources, merge it and resolve conflicts in the predictions with other information to generate a Virtual Natural Environment (VNE). Centers of Expertise (warfare area experts) use the VNE in automated tactical decision aids (TDA) to make judgments on the ability to perform certain operations and determine a measure of risk imposed by the environment. Remote users afloat or ashore can examine the products from both the Domain Authorities and the Centers of Expertise before conducting operations.

TEDServices incorporates several procedures and new developments to compensate for the diminishing bandwidth between Production Center and Remote User:

A. The first is a VNE data cache that is forward deployed to respective components.
B. Next, to minimize the amount of data passing over the network, TEDServices Clients use a MetOc/Mission Rules Based Data Order (MRBDO) process to subscribe only to relevant data by mission, area of interest, platform, parameter, application or product.
C. This function is complemented by a Local Data Broker (LDB) that minimizes reach back requirements. The LDB knows what data is stored locally, and how to contact other TEDServices GateWays to request just the needed products in their area of interest.
D. For large data transfers TEDServices employs Resumable Object Streams (ROS) for all traffic between major components. In the event of a loss of network connection by either the client or server, ROS knows how much data was transmitted. When the network comes back up, ROS continues data transfer where it left off. Retransmission is not required.
E. At the user end a development called Collaborative Application Sharing Process (CASP) allows remote application users to share the "state" of their applications across the Internet. For instance an expert at a Center of Expertise can use the VNE in a TDA to arrive at a particular decision and share only the settings on his machine with a remote user. The remote user receives only the "state" of the expert's application and uses that information in his local VNE and TDA to examine the results with a minimum of data transfer.

TEDServices was demonstrated in three fleet exercises in 2003 and will be transitioned to operational status in FY04. Currently TEDServices is focusing on meteorological data and ASW support. The Architecture is expandable and is to eventually include all types of environmental data used by the navy. The Architecture includes techniques to incorporate Through The Sensor (TTS) data. In that concept TTS data would be sent from the collecting unit to a fusion site for subsequent validation, merging, and incorporation into the VNE.

5 Summary

Existing environmental data are inadequate to support our current emphasis on the littoral warfare mission requiring high-density information in shallow water. Temporal and spatial variability in near shore areas further exacerbates the problem. Environmental data relevant to tactical operations cannot be obtained solely through routine surveys but additionally must be acquired from combatant sensor systems. Combatant systems will be the first and perhaps the only systems to enter an area of operation before conflict begins

With the move to organic mine warfare, environmental data collected from tactical sensors like the AQS-20, BQN-17, UQN-4, etc. must be fused with historical information to assemble the "best" environmental picture. Environmentally adaptive sensors are needed to improve the efficiency of data collection and to provide a true sense of coverage as conditions change during data collection. TEDServices provides an architecture that ties all of the pieces together giving a user the potential to take tactical advantage of the environment.

6 Acknowledgments

This work was sponsored under Program Element 0603704N by the Oceanographer of the Navy via SPAWAR PMW 155, Captain Bob Clark, Program Manager; The Naval Research Laboratory Program Element 0602435N, Dr. Herb Eppert and Dr. Eric Hartwig; and the Office of Naval Research , Dr. Doug Todoroff and Dr. Tom Swean Program Managers. The authors also acknowledge Captain L.F. Morris, Program Manager, Airborne Mine Countermeasures Program Office, and Captain Terry Briggs, Surface Mine Warfare Program Office, for the cooperation and assistance received from their offices. Finally, we acknowledge the many dedicated engineers and scientists at the Coastal Systems Station, Naval Oceanographic Office, Raytheon, and Lockheed Martin who have provided test support, requirements, and other information in support of Through The Sensor environmental data extraction.

7 References

[1] Inside the Navy; 28 July 2003; http://www.insidedefense.com/

[2] Brian Bourgeois, Mike Harris, Pete Alleman, Jami Cheramie and John Gravley, "Autonomous Bathymetric Surveying," Proceedings of the 10th International Symposium on Unmanned Untethered Submersible Technology, Durham, NH, September 1997

[3] Donald Brandon, Brian Bourgeois, "An Introduction to AutoSurvey and Current AutoSurvey Projects," Proceedings of the U.S. Hydrographic 2003 Conference, Biloxi, MS, 24-27MAR03

---

[4] Nicholas P. Chotiros, James M. Estes, Kent N. Scarbrough, S. Patrick Pitt, and Rudy V. Klinksiek; "Sonar coverage mapping;" Journal of the Society for Counter-Ordnance Technology, 27 May 2002. http://www.demine.org/SCOT/Papers/pdfpapers.html

[5] D.N. Lambert, D.J. Walter, D.C. Young, and M.D. Richardson, "High Resolution Acoustic Seafloor Classification System for Mine Countermeasures Operations," International Conference on Underwater Acoustics, U. of New South Wales, 5-7 December 1994.

[6] Bentrem, Frank W., John Sample, Maria T. Kalcic, and Michael E. Duncan; "High-Frequency Acoustic Sediment Classification in Shallow Water;" Oceans 2002, October, Biloxi, MS

[7] Michael M. Harris, William E. Avera, L. Dale Bibee and J. Mark Null "Environmental Data Collection from the AQS-20;" Journal of the Society for Counter-Ordnance Technology, 27 May 2002. http://www.demine.org/SCOT/Papers/pdfpapers.html

[8] Buchanan, Dr. H. Lee, and LCDR John M. Cottingham, "Countering Mines in 2005," Sea Technology, January 2000.

[9] Bibee, L. Dale, Douglas N. Lambert, Chad Vaughan, Donald J. Walter, William E. Avera, and Michael M. Harris "Sediment Classification Using Fleet Sonars;" 5th International Symposium on Technology and the Mine Problem, Monterey CA, 22-25 April 2002.

[10] Mike Harris, Kevin Shaw, Frank McCreedy, Roy Ladner, Ruth Wilson, Elizabeth Warner, Udaykiran Katikaneni, John Sample; "Access to Environmental Data Via NRL's Geospatial Information DataBase;" MREP 2003, LaSpezia, Italy, 12-16 May 2003.